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### Coccidian Parasites (Apicomplexa: Eimeriidae) of *Microtus* spp. (Rodentia: Arvicolidae) from the United States, Mexico, and Japan, with Descriptions of Five New Species

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# COCCIDIAN PARASITES (APICOMPLEXA: EIMERIIDAE) OF *MICROTUS* SPP. (RODENTIA: ARVICOLIDAE) FROM THE UNITED STATES, MEXICO, AND JAPAN, WITH DESCRIPTIONS OF FIVE NEW SPECIES

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**ABSTRACT:** Beginning in July 1980, 149 voles (*Microtus* spp.) representing 9 species and 14 subspecies collected in Japan, Mexico and the United States were examined for coccidia; 67 (45%) had oocysts in their feces. These included 1 of 3 (33%) *M. californicus sactidiegi*; 0 of 1 *M. longicaudus longicaudus*; 0 of 1 *M. l. macrurus*; 48 of 111 (43%) *M. mexicanus* including 11 of 26 (42%) *M. m. fulviventer*, 1 of 2 (50%) *M. m. fundatus*, 13 of 31 (42%) *M. m. mexicanus*, 1 of 4 (25%) *M. m. mogollonensis* and 22 of 48 (46%) *M. m. subsimus*; 5 of 8 (63%) *M. montanus arizonensis*; 6 of 6 *M. montebelli montebelli*; 2 of 4 (50%) *M. oregoni oregoni*; 5 of 13 (38%) *M. pennsylvanicus pennsylvanicus*; 0 of 1 *M. quasiater* and 0 of 1 *M. townsendii townsendii*. The following coccidians were identified from infected voles: *Eimeria saxei* n. sp. (syn. *E. wenrichi* "B") from *M. c. sactidiegi*; *E. ochrogasteri*, *E. saxei*, *E. wenrichi* (syn. *E. wenrichi* "A"), and *Eimeria* sp. from *M. m. fulviventer*; *Eimeria* sp. from *M. m. fundatus*; *E. ochrogasteri*, *E. saxei*, *Eimeria tolucadensis* n. sp., *E. wenrichi*, and *Eimeria* sp. from *M. m. mexicanus*; *E. wenrichi* from *M. m. mogollonensis*; *Eimeria coahuiliensis* n. sp., *E. saxei*, *Eimeria subsimi* n. sp., *E. wenrichi*, *Eimeria* sp., and *Isospora mexicanasubsimi* n. sp. from *M. m. subsimus*; *E. tamiasciuri* and *E. wenrichi* from *M. m. arizonensis*; *Eimeria* spp. from *M. m. montebelli*; *E. saxei* and *E. wenrichi* from *M. o. oregoni*; and *E. ochrogasteri* and *E. wenrichi* from *M. p. pennsylvanicus*. Sporulated oocysts of *Eimeria coahuiliensis* n. sp. were ellipsoid,  $29.6 \times 19.6$  ( $27\text{--}34 \times 18\text{--}22$ )  $\mu\text{m}$  with ovoid sporocysts  $14.4 \times 8.9$  ( $13\text{--}18 \times 8\text{--}10$ )  $\mu\text{m}$ . Sporulated oocysts of *Eimeria saxei* n. sp. were subspheroid,  $13.0 \times 11.0$  ( $11\text{--}14 \times 10\text{--}12$ )  $\mu\text{m}$  with ovoid sporocysts  $7.5 \times 4.0$  ( $6\text{--}9 \times 4\text{--}5$ )  $\mu\text{m}$ . Sporulated oocysts of *Eimeria subsimi* n. sp. were ovoid/subspheroid,  $25.1 \times 18.7$  ( $22\text{--}28 \times 17\text{--}21$ )  $\mu\text{m}$  with ellipsoid sporocysts  $13.9 \times 7.4$  ( $13\text{--}15 \times 6\text{--}8$ )  $\mu\text{m}$ . Sporulated oocysts of *Eimeria tolucadensis* n. sp. were subspheroid,  $25.4 \times 20.3$  ( $23\text{--}26 \times 19\text{--}23$ )  $\mu\text{m}$  with ellipsoid sporocysts  $11.3 \times 7.8$  ( $10\text{--}13 \times 7\text{--}9$ )  $\mu\text{m}$ . Sporulated oocysts of *Isospora mexicanasubsimi* n. sp. were subspheroid,  $23.7 \times 23.1$  ( $21\text{--}26 \times 21\text{--}26$ )  $\mu\text{m}$  with ovoid sporocysts  $14.9 \times 10.8$  ( $12\text{--}16 \times 10\text{--}12$ )  $\mu\text{m}$ . Only 6 of 67 (9%) infected voles were found to be naturally infected with more than a single coccidium. The world literature on coccidian parasites of voles (1 caryosporan, 31 eimerians, 1 frankelian, 2 isosporans, 4 sarcocystans, exclusive of the 5 new species described here) was reviewed.

In an ongoing study at the University of New Mexico we are examining the evolutionary relationships of various groups of small mammals using morphologic (skin, skeleton), genetic (karyotypes, enzyme electrophoresis) and parasite (mainly coccidia) data. When the distributions and genetic relatedness of many different host species are clearly documented we may, perhaps, have a better understanding of host susceptibility, parasite burdens, host specificity (or lack thereof), and coevolutionary mechanisms. The first 2 papers on parasites reviewed the coccidia from jumping mice, *Zapus* spp. (Duszynski et al., 1982), and kangaroo rats, *Dipodomys* spp. (Stout and Duszynski, 1983). Here we review the world literature on coccidians from voles (*Microtus* spp.) and report 5 new species found in hosts from Japan, Mexico and the United States.

## MATERIALS AND METHODS

Fecal samples were collected from hosts live-trapped in the field and stored in 2% (w/v) aqueous potassium dichromate ( $\text{K}_2\text{Cr}_2\text{O}_7$ ) as previously described (Duszynski et al., 1982) except that samples taken in Japan were collected and stored in 2% (v/v) aqueous sulfuric acid ( $\text{H}_2\text{SO}_4$ ). Methods for storing and processing of fecal samples upon return to the lab and for concentrating, measuring and photographing oocysts have been described in detail (Duszynski et al., 1982; Stout and Duszynski, 1983). All measurements are in micrometers with size ranges in parentheses following the means.

## RESULTS

The coccidians, the hosts they infected, and our collection localities are presented in Table I.

### Coccidians

#### *Eimeria coahuiliensis* n. sp. (Figs. 1–3, 14)

#### Description

Oocyst ellipsoid, slightly flattened at end opposite micropyle (arrow, Fig. 1), wall  $\sim 2.0$  ( $1.5\text{--}2.3$ ), com-

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TABLE I. *Eimeria* and *Isospora* spp. recovered from 14 subspecies of *Microtus* collected from the United States, Mexico and Japan.

<i>Microtus</i> spp.	Country: county and/or state	No. hosts infected/examined (%)	<i>Eimeria/Isospora</i> identified (see text)
<i>californicus sactidiegi</i>	USA: San Bernadino Co., CA	1/3 (33.3)	<i>saxei</i> *†
<i>longicaudus longicaudus</i>	USA: Apache Co., AZ	0/1	—
<i>longicaudus macrurus</i>	USA: Kittatas Co., WA	0/1	—
<i>mexicanus fulviverter</i>	Mexico: Oaxaca	11/26 (42.3)	<i>ochrogasteri</i> ,*† <i>saxei</i> ,*† <i>wenrichi</i> ,*† sp.‡
<i>mexicanus fundatus</i>	Mexico: Michoacan	1/2	sp.‡
<i>mexicanus mexicanus</i>	Mexico: Mexico Oaxaca Veracruz	5/14 (35.7) 1/2 7/15 (46.7)	<i>ochrogasteri</i> ,*† <i>saxei</i> ,*† <i>tolucadensis</i> ,*† sp.‡ sp.‡ <i>wenrichi</i> ,*† sp.‡
<i>mexicanus mogollonensis</i>	USA: Apache Co., AZ Catron Co., NM	1/1 0/3	<i>wenrichi</i> *† —
<i>mexicanus subsimus</i>	Mexico: Coahuila	22/48 (45.8)	<i>coahuiliensis</i> ,*† <i>saxei</i> ,*† <i>subsimi</i> ,*† <i>wenrichi</i> ,*† sp.‡ <i>mexicanasubsimi</i> *†
<i>montanus arizonensis</i>	USA: Apache Co., AZ	5/8 (62.5)	<i>tamiasciuri</i> ,*† <i>wenrichi</i> *†
<i>montebelli montebelli</i>	Japan: Nezano, Honshu	6/6	spp.‡
<i>oregoni oregoni</i>	USA: Clallam Co., WA	2/4	<i>saxei</i> ,*† <i>wenrichi</i> *†
<i>pennsylvanicus pennsylvanicus</i>	USA: Ashtabula Co., CA Franklin Co., MA Warren Co., PA	0/1 5/11 (36.4) 0/1	— <i>ochrogasteri</i> ,*† <i>wenrichi</i> † —
<i>quasiater</i>	Mexico: Veracruz	0/1	—
<i>townsendii townsendii</i>	USA: Pierce Co., WA	0/1	—

\* New host record.

† New locality (state or country) record.

‡ Unsporulated oocysts of one (sp.) or more (spp.) morphs; unable to identify.

posed of 2 layers: inner layer membranous, colorless, outer layer rough, golden-amber,  $\sim 3/4$  of total thickness; micropyle (arrow, Fig. 2) 2.8 and polar body (Fig. 3) present; oocyst residuum absent; sporulated oocysts ( $n = 46$ )  $29.6 \times 19.6$  ( $27-34 \times 18-22$ ) with L:W ratio 1.53 (1.23–1.68); sporocysts ( $n = 43$ ) ovoid,  $14.4 \times 8.9$  ( $13-18 \times 8-10$ ) with L:W ratio 1.59 (1.36–2.01); Stieda body present; sporocyst residuum composed of dispersed, equatorially-located granules; each sporozoite with 2 refractile bodies. Oocysts were 168–342 days old when measured.

### Taxonomic summary

**Diagnosis:** This eimerian does not resemble any previously described coccidian from voles.

**Host:** *Microtus mexicanus subsimus* Goldman, 1938, Museum of Southwestern Biology, Division of Mammalogy, NK 9540 (male), D. W. Moore #1025, 24 July 1982 and NK 9542 (female), D. W. Moore #1027, 24 July 1982.

**Locality:** 14.8 km E of San Antonio de las Alazanas, Coahuila, Mexico.

**Prevalence:** Found in 2 of 22 (9%) infected *M. m. subsimus* collected in San Antonio de las Alazanas.

**Site of infection:** Unknown, oocysts recovered from fecal contents.

**Etymology:** The specific name is derived from the locality of the host.

### *Eimeria ochrogasteri* Ballard, 1970

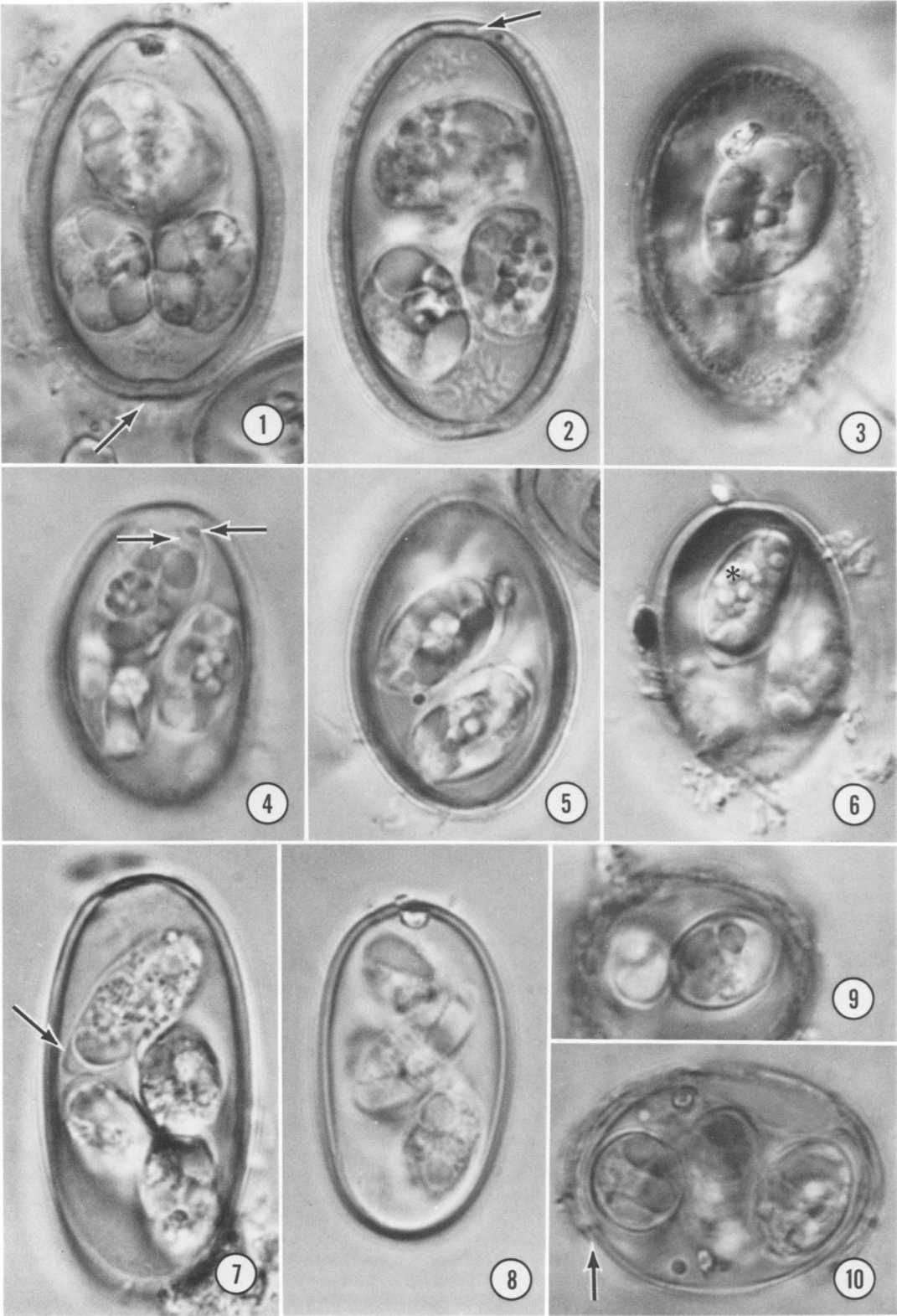
Oocysts of this species were found in 3 of 11 (27%) infected *M. m. fulviverter*, 2 of 13 (15%) infected *M. m. mexicanus*, and 1 of 5 (20%) infected *M. p. pennsylvanicus*. This species has already been well described and our observations agree with those of Ballard (1970).

### *Eimeria saxei* n. sp.

(Fig. 11)

### Description

Oocyst small-ellipsoid to subspheroid with smooth, thin wall ( $<1.0$ ); micropyle and oocyst residuum absent, but a polar body is present; sporulated oocysts ( $n = 20$ )  $13.0 \times 11.0$  ( $11-14 \times 10-12$ ) with L:W ratio



1.18 (1.10–1.40); sporocysts (n = 20) ovoid 7.5 × 4.0 (6–9 × 3–5) with L:W ratio 1.87 (1.50–2.25); Stieda body and compact sporocyst residuum are present. Oocysts were 418 days old when measured.

#### Taxonomic summary

**Diagnosis:** This species corresponds to the ‘small form’ or “*Eimeria wenrichi* species B” of Saxe et al. (1960). In the original description of *E. wenrichi*, the authors noted 2 distinct groups of similar oocysts that did not overlap in oocyst or sporocyst dimensions, but which otherwise shared all other structural features. In their paper, based on 87 oocysts from 1 *M. pennsylvanicus*, they found 56 oocysts (“species A”) were 18.9 × 14.3 (16–22 × 12–16) with sporocysts 9.7 × 6.0 (9–11 × 5–8) and 31 oocysts (“species B”) were 12.8 × 9.8 (11–15 × 8–11) with sporocysts 6.9 × 4.0 (6.5–7.5 × 4.0) and concluded, “. . . the two series of oocysts . . . formed completely separate populations.” For some reason, however, they decided it did “not appear wise to assign them different names, even though future studies may show they differ in some other way and are actually separate species.” There is certainly sufficient precedent in the literature to show that coccidians with similar structural features, but distinctly different oocyst and sporocyst dimensions, are distinct species. Many eimerians (see Duszynski, 1971 for review) are known to have oocysts that increase or decrease in size during patency. However, if this were the case with *E. wenrichi*, one would expect length-width dimensions to vary over a continuous range. In the original description, a distinct bimodal size distribution was seen and in all the hosts we saw infected with either *E. wenrichi* (“species A”) or *E. saxei* (“*E. wenrichi* species B”) oocysts were either one size or the other, with no intermediate forms. Based on these data we feel it is warranted to separate the 2 forms of *E. wenrichi* into separate species.

**Type host:** *Microtus pennsylvanicus* (Ord, 1815).

**Type locality:** Pennsylvania, U.S.A.

**Other hosts and localities:** See Table I.

**Prevalence:** Found in 1 *M. pennsylvanicus* (Saxe et al., 1960). In this study it occurred in the 1 infected *M. c. sactidiegi*, in 1 of 11 (9%) infected *M. m. fulviventer*, in 1 of 13 (8%) infected *M. m. mexicanus*, in 3 of 22 (14%) infected *M. m. subsimus*, and in 1 of 2 infected *M. o. oregoni*.

**Site of infection:** Unknown, oocysts recovered from fecal contents.

**Etymology:** This parasite is named for Dr. L. H. Saxe who was senior author of the paper that first described it (Saxe et al., 1960).

#### *Eimeria subsimi* n. sp.

(Figs. 4–6, 15)

#### Description

Oocysts ovoid (Fig. 5) to subspheroid, wall 1.6 (1.5–1.8) with outer layer slightly sculptured comprising ~% of total thickness; polar body present, but oocyst residuum and micropyle are absent; sporulated oocysts (n = 47) 25.1 × 18.7 (22–28 × 17–21) with L:W ratio 1.31 (1.03–1.54); sporocysts (n = 45) ellipsoid 13.9 × 7.4 (13–15 × 6–8) with L:W ratio 1.93 (1.63–2.00); Stieda and substieda bodies present (arrows, Fig. 4); sporocysts contain a compact, faceted residuum (aster, Fig. 6) which may be associated with a few dispersed granules; sporozoites lie head to tail within sporocyst and contain refractile bodies. Oocysts were 155–363 days old when measured.

#### Taxonomic summary

**Diagnosis:** This species somewhat resembles *E. iradiensis* Veisov, 1963, in general size, shape and color, but differs by having oocysts that have a slightly sculptured outer wall (vs. smooth), by having a polar body, and by having longer sporocysts ( $\bar{x}$  = 14 vs.  $\bar{x}$  = 11) that possess a substieda body which *E. iradiensis* lacks. Host and geographic distance may also dictate we are dealing with a new species.

**Host:** *Microtus mexicanus subsimus* Goldman, 1938, Museum of Southwestern Biology, Division of Mammalogy, NK 9515 (female), L. L. Janecek #130, 23 July 1982 and NK 9542 (female), D. W. Moore #1027, 24 July 1982.

**Locality:** 16.1 km E of San Antonio de las Alazanas (NK 9515), and 14.8 km E of San Antonio de las Alazanas (NK 9542), Coahuila, Mexico.

**Prevalence:** Found in 2 of 22 (9%) infected *M. m. subsimus* collected in Coahuila, Mexico.

**Site of infection:** Unknown, oocysts recovered from fecal contents.

**Etymology:** The specific name is derived from the subspecific part of the scientific name of the host.

#### *Eimeria tamiasciuri* Levine, Ivens, and Kruidenier, 1957

(Figs. 7 and 8)

#### Description

Oocyst elongate ellipsoid, smooth wall ~1.0, appears single-layered; a polar body, sometimes (11%) associated with one pole (Fig. 8), is present but a micropyle and oocyst residuum are lacking; sporulated oocysts (n = 104) 30.3 × 17.1 (23–37 × 13–19) with L:W ratio 1.80 (1.60–2.55); sporocysts (n = 102) ellipsoid 14.8 × 6.7 (10–17 × 6–8) with L:W ratio 2.18 (1.60–2.80); a

←

FIGURES 1–10. Photomicrographs of sporulated oocysts of coccidians recovered from the feces of *Microtus* spp. ×1,840. 1–3. *Eimeria coahuiliensis* n. sp. from *M. m. subsimus*. 1. Flattened end (arrow) opposite micropyle. 2. Micropyle (arrow). 3. Note polar body. 4–6. *Eimeria subsimi* n. sp. from *M. m. subsimus*. 4. Stieda and substieda bodies (arrows). 5. Note polar body and ovoid shape. 6. Faceted sporocyst residuum (\*). 7, 8. *Eimeria tamiasciuri* Levine, Ivens, and Kruidenier, 1957. 7. Conical Stieda body (arrow). 8. Note variation in size of oocysts and terminal location of polar body in some oocysts. 9, 10. *Eimeria tolucadensis* n. sp. from *M. m. mexicanus*. 9. Ellipsoid sporocyst and its residuum. 10. Fragmented piece of oocyst outer wall (arrow).



FIGURES 11–13. Photomicrographs of sporulated oocysts of coccidians recovered from the feces of *Microtus* spp.  $\times 1,840$ . 11. *Eimeria saxei* n. sp. from *M. c. sactidiegi*. 12. *Eimeria wenrichi* Saxe, Levine, and Ivens, 1960 from *M. m. subsimus*. 13. *Isospora mexicanasubsimi* n. sp. from *M. m. subsimus*; note prominent substieda body (arrow).

prominent, conical Stieda body (arrow, Fig. 7) and a finely granular, dispersed sporocyst residuum are present; sporozoites with at least 1 refractile body each. Oocysts were 97 days old when measured.

#### Taxonomic summary

**Diagnosis:** Oocysts of this parasite do not resemble those from any eimerian reported from voles and our initial thought was to describe it as new. However, the geographic range of the red squirrel *Tamiasciurus hudsonicus mogollonensis* in Arizona completely overlaps the limited distribution of *M. m. arizonensis* in east-central Arizona (Hall, 1981a, 1981b). Levine et al. (1957) described *E. tamiasciuri* oocysts from the red squirrel, *T. h. mogollonensis*, in Arizona and the oocysts we found in *M. m. arizonensis* from eastern Arizona are indistinguishable from them. They are also indistinguishable from *E. tamiasciuri* oocysts we have recovered from chipmunks (*Eutamias* spp.) in Arizona, California and Mexico (unpubl.). Although oocysts were found in large numbers in our infected vole, this may be a spurious finding since only 1 Arizona vole was found to harbor them. On the other hand, until cross-transmission studies can prove otherwise, *E. tamiasciuri* may be a valid parasite of *Microtus*.

**Host:** *Microtus montanus arizonensis* Bailey, 1898, Museum of Southwestern Biology, Division of Mammalogy, MSB 53569 (male), D. W. Moore #1179, 24 September 1983.

**Locality:** 25.7 km W, 6.4 km S Alpine, TSN R28E, SW  $\frac{1}{4}$  sec. 29, Westfork Campground, Apache Co., Arizona.

**Prevalence:** Found in 1 of 5 (20%) infected *M. m. arizonensis* collected from Apache Co., Arizona.

**Site of infection:** Unknown, oocysts recovered from fecal contents.

#### *Eimeria tolucadensis* n. sp. (Figs. 9, 10, 16)

#### Description

Oocysts subspheroid or nearly so, wall 2.3 (2–3) with outer, multilaminar layer comprising  $\sim \frac{2}{3}$  of total thick-

ness (Fig. 10); inner layer smooth; 1 or more polar bodies present, but micropyle and oocyst residuum are absent; sporulated oocysts ( $n = 11$ )  $25.4 \times 20.3$  ( $23\text{--}26 \times 19\text{--}23$ ) with L:W ratio 1.25 (1.15–1.40); sporocysts ( $n = 11$ ) ellipsoid  $11.3 \times 7.8$  ( $10\text{--}13 \times 7\text{--}9$ ) with L:W ratio 1.44 (1.26–1.70); an inconspicuous Stieda body is present (Fig. 9), but not a substieda body; sporocyst residuum present and consists of 4 to 6 small globules; sporozoites contain 1 or 2 refractile bodies. Oocysts were 313 days old when measured.

#### Taxonomic summary

**Diagnosis:** Oocysts of this species do not fit the description of oocysts from any eimerian previously described from voles; they are similar, however, to *E. baiomys* Levine, Ivens, and Kruidenier, 1958 described from *Baiomys taylori* (Thomas), which shares a common habitat range, Michoacan to Veracruz, with *M. m. mexicanus* (Hall, 1981b), except that *E. baiomys* is proportionally smaller, has a single-layered oocyst wall and contains a conspicuous oocyst residuum which is missing in *E. tolucadensis*.

**Host:** *Microtus mexicanus mexicanus* (Saussure, 1861), Museum of Southwestern Biology, MSB 48299 (female), L. L. Janecek #192, 5 August 1982.

**Locality:** 17.5 km S, 7.0 km W of Toluca, Nevado de Toluca, Mexico, Mexico.

**Prevalence:** Found in 1 of 5 (20%) infected *M. m. mexicanus* collected from Toluca, Nevado de Toluca, Mexico, Mexico.

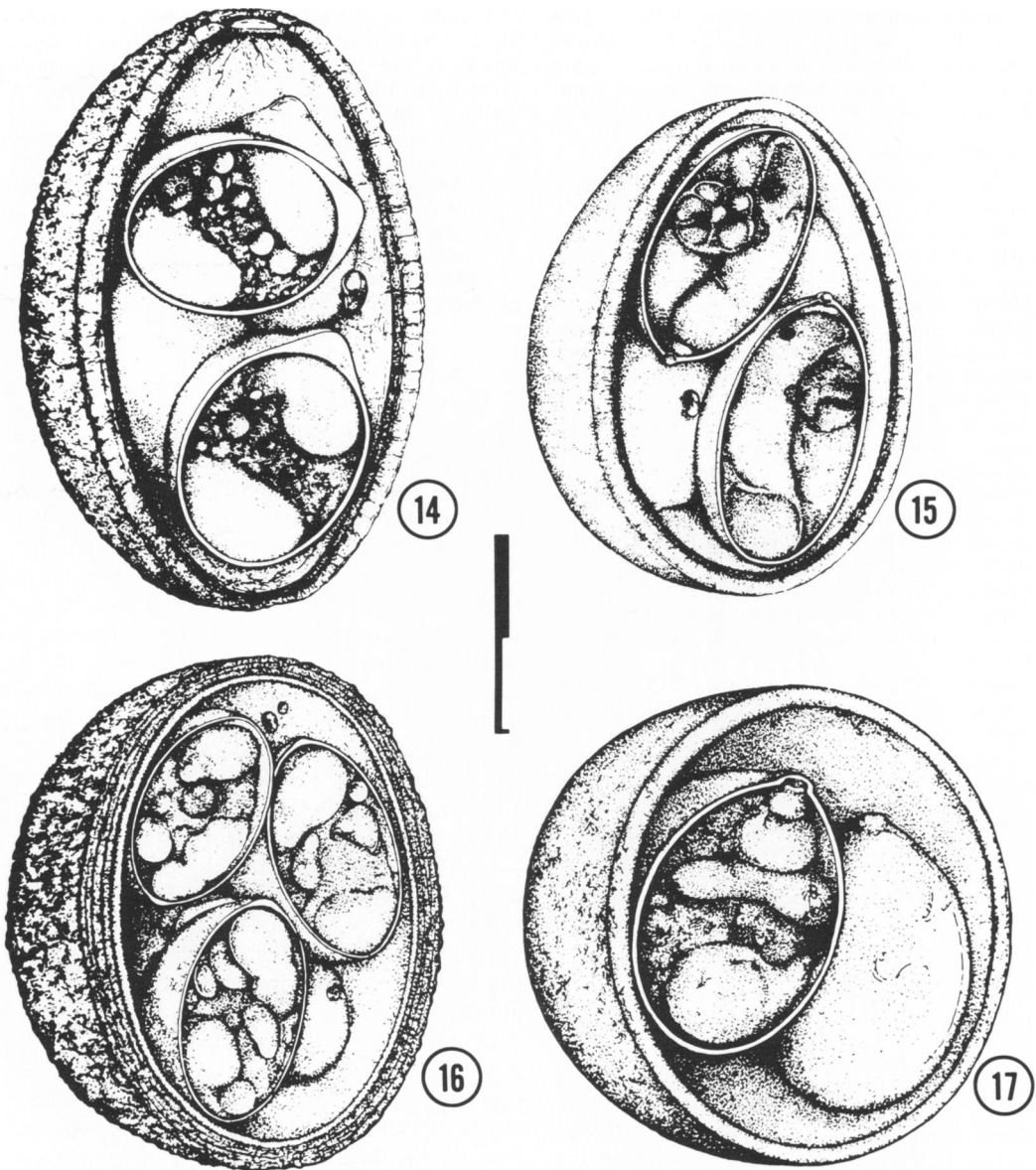
**Site of infection:** Unknown, oocysts recovered from fecal contents.

**Etymology:** The specific name is derived from the locality where the infected host was collected.

#### *Eimeria wenrichi* Saxe, Levine, and Ivens, 1960 (Fig. 12)

#### Description

Oocysts of this species were seen in 1 of 11 (9%) infected *M. m. fulviventer*, 4 of 13 (31%) infected *M. m. mexicanus*, the only infected *M. m. mogollonensis*,



FIGURES 14–17. Line drawings of sporulated oocysts of new coccidian species recovered from the feces of *Microtus* spp.; scale = 10  $\mu$ m. 14. *Eimeria coahuiliensis*. 15. *Eimeria subsimi*. 16. *Eimeria tolucadensis*. 17. *Isospora mexicanasubsimi*.

8 of 22 (36%) infected *M. m. subsimis*, 4 of 5 (80%) infected *M. m. arizonensis*, both infected *M. o. oregoni*, and all 5 infected *M. p. pennsylvanicus*. Photomicrographs of this species have not been published previously, so 1 is included (Fig. 12). All oocysts that we identified as *E. wenrichi* fit the description for the 'large form' or "*E. wenrichi* species A" in the original description by Saxe et al. (1960) (for explanation, see Diagnosis section for *E. saxeii*, above).

***Isospora mexicanasubsimi* n. sp.**

(Figs. 13 and 17)

**Description**

Oocyst spheroid or nearly so, wall  $\sim 1.5$ , bilayered with a lightly pitted outer surface and a smooth, somewhat darker inner layer; sporulated oocysts ( $n = 10$ )  $23.7 \times 23.1$  ( $21\text{--}26 \times 21\text{--}26$ ) with L:W ratio 1.03 (1.00–1.13); micropyle, oocyst residuum, and polar



body absent; sporocysts ( $n = 10$ ) ovoid  $14.9 \times 10.8$  ( $12-16 \times 10-12$ ) with L:W ratio 1.38 (1.26-1.61); sporocysts possess distinct Stieda and substieda bodies (Fig. 13) as well as a dispersed, homogeneous residuum. Oocysts were 198-213 days old when measured.

### Taxonomic summary

**Diagnosis:** Only 2 isosporans have been reported as parasites of the genus *Microtus*, *I. mcdowelli* Saxe et al., 1960 from *M. pennsylvanicus* and *I. arvalis* Mikeladze, 1974 reported from *M. arvalis*. Two other species, though, have been reported from hosts also within the family Arvicolidae. These are: *I. laguri* Iwanoff-Gobzen, 1934 and *I. teres* Iwanoff-Gobzen, 1934 reported from *Lagurus lagurus* (Pallas). The coccidian described herein did not resemble these previously reported species.

**Host:** *Microtus mexicanus subsimus* Goldman, 1938, Museum of Southwestern Biology, Division of Mammalogy, MSB 48337 (female), L. L. Janecek #121, 23 July 1982 and MSB 48332 (female), L. L. Janecek #149, 23 July 1982.

**Locality:** 16.1 km E of San Antonio de las Alazanas, Coahuila, Mexico.

**Prevalence:** Found in 2 of 22 (9%) infected *M. m. subsimus* collected from Coahuila, Mexico.

**Site of infection:** Unknown, oocysts recovered from fecal contents.

**Etymology:** The specific name is derived from the specific and subspecific parts of the scientific name of the host.

### Hosts

Of those hosts with coccidia at the time they were collected, the following parasites, or groups of parasites were seen.

*Microtus californicus sactidiegi* Kellogg, 1918. The 1 infected vole of this species had oocysts of *E. saxei* in its feces.

*Microtus mexicanus fulviventer* Merriam, 1898. All 11 infected voles were singly-infected with either *E. ochrogasteri* (3), *E. saxei* (1), *E. wenrichi* (1), or *Eimeria* sp. (6).

*Microtus mexicanus fundatus* Hall, 1948. The only infected vole was singly-infected with unsporulated oocysts of a single morph.

*Microtus mexicanus mexicanus* (Saussure, 1861). We found 12 of 13 (92%) infected voles singly-infected with either *E. ochrogasteri* (1), *E. saxei* (1), *E. wenrichi* (4), or *Eimeria* sp. (6); 1 vole harbored 2 coccidians: *E. ochrogasteri* and *E. tolucadensis*.

*Microtus mexicanus mogollonensis* (Mearns, 1890). The only infected vole was singly-infected with *E. wenrichi*.

*Microtus mexicanus subsimus* Goldman, 1938. Nineteen of 22 (86%) infected voles were singly-infected with either *E. coahuiliensis* (1), *E. saxei* (2), *E. wenrichi* (5), *I. mexicanasubsimi* (2), or *Eimeria* sp. (9); 2 voles were doubly-infected, 1 with *E. wenrichi* and *E. saxei* and 1 with *E. wenrichi* and *E. subsimi*; 1 vole was infected with 3 species, *E. coahuiliensis*, *E. subsimi*, and *E. wenrichi*.

*Microtus montanus arizonensis* Bailey, 1898. All 5 infected voles were singly-infected with either *E. tamiasciuri* (1) or *E. wenrichi* (4).

*Microtus montebelli montebelli* (Milne-Edwards, 1872). All 6 infected voles had oocysts that never sporulated. Four of 6 (67%) had oocysts of only a single morph; the other 2 infected hosts had oocysts of 2 distinctly different morphs.

*Microtus oregoni oregoni* (Bachman, 1839). One of 2 infected voles was singly-infected with *E. wenrichi*, the other was doubly-infected with *E. saxei* and *E. wenrichi*.

*Microtus pennsylvanicus pennsylvanicus* (Ord, 1815). Four of 5 (80%) infected voles were singly-infected with *E. wenrichi*; 1 infected vole was infected with both *E. ochrogasteri* and *E. wenrichi*.

### DISCUSSION

The majority of the literature on the Coccidia of voles (*Microtus* spp.) originates from Eurasian sources, which describe 29 eimerians, 1 isosporan, and 2 sarcocystans; in North America, only 7 species (*Caryospora microti*, *Frenkelia microti*, *Eimeria orchogasteri*, *E. wenrichi* "A" and "B," *Isospora mcdowelli*, *Sarcocystis microti* and *S. montanaensis*) have been reported prior to the species we describe here (Table II). According to recent taxonomic schemes (Honacki et al., 1982), *Microtus* is the most speciose of 20 genera assigned to the family Arvicolidae. In addition to the 39 coccidians described previously from *Microtus* spp., 6 other genera in the family (*Alticola*, *Clethrionomys*, *Discrostonyx*, *Ellobius*, *Lagurus*, *Ondatra*) have been identified as hosts of at least 17 additional coccidian species (Levine, 1951; Levine and Ivens, 1965; Pellérdy, 1974; Golemansky, 1979). None of the 56 coccidians previously described from arvicolids resembled the new species described here, other than the similarities already noted.

On the other hand, as we measure and identify numerous coccidians from thousands of specimens of both closely related and unrelated mammalian species, we are beginning to see oocysts that are identical or nearly so from genetically unrelated, but geographically sympatric host species. For example, here we point out that oocysts of *E. tamiasciuri*, originally described from the red squirrel (*T. h. mogollonensis*) were also found in large numbers in a *M. m. arizonensis* and in several groups of chipmunks (unpubl.). Also in our work with other genera of small mammals we have seen more substantive examples of oocysts described from one host genus commonly found in the feces of unrelated hosts (e.g., *Perognathus* and *Dipodomys* spp.; *Peromyscus* and *Neotoma* spp.; and others, unpubl. data). Obviously, there is much cross-transmission work to be done before such prob-

TABLE II. *Coccidian parasites of Eurasian and North American Microtus spp. described to date.*

Coccidian spp.	<i>Microtus</i> spp.	Reference used
<i>Caryospora microti</i>	<i>pennsylvanicus</i>	Saxe et al., 1960
<i>Eimeria abuschevi</i>	<i>majori</i>	Veisov, 1962
<i>E. arvicolae</i>	<i>arvalis, nivalis</i>	Veisov, 1963
<i>E. bicrustae</i>	<i>majori</i>	Veisov, 1962
<i>E. chetae</i>	<i>middendorfi</i>	Arnastauskene, 1980
<i>E. chudatica</i>	<i>socialis</i>	Musaev et al., 1963
<i>E. coahuiliensis</i>	<i>mexicanus</i>	present study
<i>E. correptionis</i>	<i>majori</i>	Veisov, 1962
<i>E. cubinica</i>	<i>socialis</i>	Musaev et al., 1963
<i>E. cusarica</i>	<i>socialis</i>	Musaev et al., 1963
<i>E. derenica</i>	<i>arvalis</i>	Veisov, 1963
<i>E. dzulfaensis</i>	<i>socialis</i>	Pellérdy, 1974
<i>E. gomurchaica</i>	<i>arvalis</i>	Veisov, 1963
<i>E. guentherii</i>	<i>guentheri</i>	Golemansky, 1978
<i>E. hadrutica</i>	<i>socialis</i>	Musaev et al., 1963
<i>E. iradiensis</i>	<i>arvalis</i>	Veisov, 1963
<i>E. iwanoffi</i>	<i>arvalis</i>	Veisov, 1963
<i>E. kolabski</i>	<i>socialis</i>	Pellérdy, 1974
<i>E. kolanica</i>	<i>arvalis</i>	Veisov, 1963
<i>E. kotuji</i>	<i>middendorfi</i>	Arnastauskene, 1980
<i>E. luteola</i>	<i>middendorfi</i>	Arnastauskene, 1980
<i>E. majorici</i> (syn. <i>E. arvalis</i> )	<i>majori</i>	Veisov, 1962
<i>E. micropiliana</i>	<i>socialis</i>	Musaev et al., 1963
<i>E. microtina</i>	<i>socialis</i>	Pellérdy, 1974
<i>E. middendorfi</i>	<i>middendorfi</i>	Arnastauskene, 1977
<i>E. monocrustae</i>	<i>arvalis</i>	Veisov, 1963
<i>E. ochrogasteri</i>	<i>ochrogasteri, mexicanus, pennsylvanicus</i>	Ballard, 1970, present study
<i>E. pitymydis</i>	<i>Pitymys subterraneus</i> *	Golemansky, 1979
<i>E. primbelica</i>	<i>arvalis</i>	Veisov, 1963
<i>E. schelkovnikovii</i>	<i>schelkovnikovii</i>	Musaev, 1967
<i>E. saxei</i> (syn. <i>E. wenrichi</i> "B")	<i>californicus, mexicanus, oregoni</i>	present study
<i>E. subsimi</i>	<i>mexicanus</i>	present study
<i>E. taimyrica</i>	<i>middendorfi</i>	Arnastauskene, 1977
<i>E. tamiasciuri</i>	<i>montanus</i>	present study
<i>E. tolucadensis</i>	<i>mexicanus</i>	present study
<i>E. wenrichi</i> (syn. <i>E. wenrichi</i> "A")	<i>pennsylvanicus</i>	Saxe et al., 1960
<i>E. zuvandica</i>	<i>arvalis</i>	Veisov, 1963
<i>Frenkelia microti</i>	<i>agrestis</i>	Biocca, 1968
<i>Isospora arvalis</i>	<i>arvalis</i>	Mikeladze, 1974
<i>I. mcdowelli</i>	<i>pennsylvanicus</i>	Saxe et al., 1960
<i>I. mexicanasubsimi</i>	<i>mexicanus</i>	present study
<i>Sarcocystis cernae</i>	<i>arvalis</i>	Levine, 1977
<i>S. microti</i>	<i>pennsylvanicus</i>	Dubey, 1983
<i>S. montanaensis</i>	<i>pennsylvanicus</i>	Dubey, 1983
<i>S. putorii</i>	<i>arvalis, agrestis</i>	Tadros and Laarman, 1978

\* According to Nowak and Paradisio (1983) *Pitymys* is now a subgenus of *Microtus*.

lems as host specificity can be addressed in these instances, but perhaps a lack of host specificity among eimerians, such as that seen by de Vos (1970), for *E. chinchillae*, is more widespread than we suspect. It is also likely that geographic and ecologic factors play much more of an important role in host-specificity than previously given credit.

It seems axiomatic that certain groups of mammals would be at greater risk of infection by coccidians than other mammalian groups simply because of the natural environments in which they live. For example voles, which live

in mesic grasslands should have a higher incidence of infection with coccidians than say kangaroo rats (*Dipodomys* spp.) which live in xeric environments simply because the former environments (grassland) would be more conducive to oocyst survival than the latter (desert). At least some support for this generalization is available. In a previous study (Stout and Duszynski, 1983) only 104 of 361 (29%) kangaroo rats (7 species, 13 collection localities) harbored coccidia when examined; whereas in the present study 67 of 149 (45%) voles (9 species, 15 collection localities) had oocysts in their feces when examined.

When we examine the individual infected animals in this and our other recent surveys we see that a very high percentage of infected hosts had only one coccidian species when examined. In *Zapus* spp. (Duszynski et al., 1982) 29 of 29 (100%) infected hosts, in *Dipodomys* spp. (Stout and Duszynski, 1983) 88 of 104 (85%) infected hosts, in *Peromyscus* spp. (Reduker et al., 1985) 97 of 106 (92%) infected hosts, and in *Microtus* spp. (this study) 61 of 67 (91%) infected hosts had only single species infections when examined. This may indicate there is strong selective advantage for certain host groups to maintain only one coccidian species at any one time. It will be interesting to learn if this observation is consistent from host to host as more data become available.

It should be noted that all oocysts recovered from the feces of *M. m. montebelli* were deteriorated and/or unsporulated when examined. Samples taken from this host species were stored and processed in 2% (v/v) aqueous  $H_2SO_4$ ; though others (Frenkel and Dubey, 1975; Ruiz and Frenkel, 1980) have used 2%  $H_2SO_4$  to sporulate and store coccidian oocysts (e.g., *Hammondia*, *Isospora*, *Toxoplasma*), it has been our experience in this and previous field collections that  $H_2SO_4$ , when used for any long period as a storage medium, is detrimental to the survival and structural integrity of eimerian oocysts.

Finally, we note that 3 of the new species we describe, *E. coahuiliensis*, *E. subsimi* and *I. mexicanasubsimi* were all parasites in a unique karyotypic race, *Microtus mexicanus subsimus*, that is found only in our northernmost collection locality of Mexico, San Antonio de las Alazanas. All voles collected in this area had diploid numbers of 44 whereas all other voles taken in Mexico had diploid numbers of 48 (Moore, pers. comm.). Alterations in chromosomes, and the subsequent amino acid sequencing, may produce slight changes in metabolic pathways or enzyme properties to change a host's gastrointestinal physiology. Certain coccidians then might be more likely to establish, others might be rejected, while still others might be stimulated to undergo a speciation event.

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#### LITERATURE CITED

- ARNASTAUSKENE, T. V. 1977. K voprosy o zarazhenosti zhivitnykh Koktsidiiyami na Taimyre. In Problemy Epidemiologii i Profilaktiki Prirodnookhagovykh Boleznii v Zapolyar'e. G. V. Kornulova, V. K. Yastrebov and V. A. Klebanevskii (eds.). Ministerstvo Zdravookhraneniya RSFSR, Omskii Ordena Trudovogo Krasnogo Znameni Meditsinskii Institut, Omsk, U.S.S.R., pp. 135–143.
- . 1980. Characteristics of the infections of small mammals with coccidia in the Taimyr Peninsula Russian, SFSR, USSR, in 1974–1975 (text in Russian). Trudy Akademii Nauk Litovskoi SSR, Seriya B 2(90): 53–60.
- BALLARD, N. B. 1970. *Eimeria ochrogasteri* n. sp. from the prairie vole, *Microtus ochrogaster*. Journal of Protozoology 17: 271–273.
- BIOCCA, E. 1968. Class Toxoplasmata: Critical review and proposal of the new name *Frenkelia* gen. n. for M-organism. Parasitologia 10: 89–99.
- DE VOS, A. J. 1970. Studies on the host range of *Eimeria chinchillae* de Vos and Van der Westhuizen, 1968. Onderstepoort Journal of Veterinary Research 37: 29–36.
- DUBEY, J. P. 1983. *Sarcocystis montanaensis* and *S. microti* sp. n. from the meadow vole (*Microtus pennsylvanicus*). Proceedings of the Helminthological Society of Washington 50: 318–324.
- DUSZYNSKI, D. W. 1971. Increase in size of *Eimeria separata* oocysts during patency. Journal of Parasitology 57: 948–952.
- , G. EASTHAM, AND T. L. YATES. 1982. *Eimeria* from jumping mice (*Zapus* spp.): A new species and genetic and geographic features of *Z. hudsonicus luteus*. Journal of Parasitology 68: 1146–1148.
- FRENKEL, J. K., AND J. P. DUBEY. 1975. *Hammondia hammondi* gen. nov., sp. nov., from domestic cats, a new coccidian related to *Toxoplasma* and *Sarcocystis*. Zeitschrift für Parasitenkunde 46: 3–12.
- GOLEMANSKY, V. G. 1978. Description de neuf nouvelles espèces de coccidies (Coccidia: Eimeriidae), parasites de micromammifères en Bulgarie. Acta Protozoologica 17: 261–270.
- . 1979. Coccidia (Coccidia, Eimeriidae) of mammals from the Parangalista, Ropotamo and

- Srebarina reserves in Bulgaria. *Acta Zoologica Bulgarica* 0(12): 12–26.
- HALL, E. R. 1981a. The mammals of North America, 2nd ed., Vol. I. John Wiley and Sons, New York, pp. 443–444.
- . 1981b. The mammals of North America, 2nd ed., Vol. II. John Wiley and Sons, New York, pp. 725–726, 797–798, 814–815.
- HONACKI, J. H., K. E. KINMAN, AND J. W. KOEPL. 1982. Mammal species of the world. Allen Press, Inc. & the Assoc. of Systematic Collections, Lawrence, Kansas, 694 p.
- LEVINE, N. D. 1951. *Eimeria dicrostonicis* n. sp., a protozoan parasite of the lemming, and other parasites from arctic rodents. *Transactions of the Illinois Academy of Sciences* 44: 205–208.
- . 1977. *Sarcocystis cernae* sp. n. replacement name for *Sarcocystis* sp. Cerna & Louckova, 1976. *Folia Parasitologica (Praha)* 24: 316.
- , AND V. IVENS. 1965. The coccidian parasites (Protozoa, Sporozoa) of rodents. Illinois Biological Monograph No. 33. 365 p.
- , ———, AND F. J. KRUIDENIER. 1957. New species of *Eimeria* from Arizona rodents. *Journal of Protozoology* 4: 80–88.
- , ———, AND ———. 1958 (1957). New species of *Eimeria* (Protozoa: Eimeriidae) from Mexican rodents. *Transactions of the Illinois Academy of Sciences* 50: 291–298.
- MIKELADZE, L. G. 1974 (1973). A new species of Coccidia, *Isospora arvalis*, new species from the common field mouse, *Microtus arvalis* (text in Russian). *Soobshcheniya Akademii Nauk Gruzinskoi SSR* 72: 477–479.
- MUSAEV, M. A. 1967. A new species of coccidia of the genus *Eimeria* from the field mouse *Microtus (Pitymys)* *schelkovnikovi*, *Eimeria schelkovnikovi* new species (text in Russian). *Izvestiya Akademii Nauk Azerbaidzhanskoi SSR Seriya Biologicheskikh I Nauk* 1: 44–46.
- , A. M. VEISOV, AND F. K. ALIEVA. 1963. Five new coccidian species of the genus *Eimeria* from *Microtus socialis* Pallas (text in Russian). *Zoologicheskii Zhurnal U.S.S.R.* 42: 809–813.
- NOWAK, R. M., AND J. L. PARADISO. 1983. Walker's mammals of the world, Vol. 1. Johns Hopkins University Press, Baltimore, 568 p.
- PELLÉRDY, L. P. 1974. Coccidia and coccidiosis, 2nd ed. Verlag, Paul Parey, Berlin, 959 p.
- REDUKER, D. W., L. HERTEL, AND D. W. DUSZYNSKI. 1985. *Eimeria* spp. (Apicomplexa: Eimeriidae) infecting *Peromyscus* rodents in the southwestern United States and northern Mexico with description of a new species. *Journal of Parasitology* 71: (in press).
- RUIZ, A., AND J. K. FRENKEL. 1980. *Toxoplasma gondii* in Costa Rican cats. *American Journal of Tropical Medicine and Hygiene* 29: 1150–1160.
- SAXE, L. H., N. D. LEVINE, AND V. IVENS. 1960. Species of Coccidia from the meadow mouse, *Microtus pennsylvanicus*. *Journal of Protozoology* 7: 61–63.
- STOUT, C. A., AND D. W. DUSZYNSKI. 1983. Coccidia from kangaroo rats (*Dipodomys* spp.) in the western United States with descriptions of *Eimeria merriami* sp. n. and *Isospora* sp. *Journal of Parasitology* 69: 209–214.
- TADROS, W., AND J. J. LAARMAN. 1978. A comparative study of the light and electron microscopic structure of the walls of the muscle cysts of several species of sarcocystid eimeriid Coccidia: II. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series C, Biological and Medical Sciences, Netherlands 81: 486–491.
- VEISOV, A. M. 1962. New species of *Eimeria* from the shrub vole of Asia Minor *Microtus majori* Thomas, 1906 (text in Russian). *Doklady Akademii Nauk Azerbaidzhanskoi SSR* 18: 59–64.
- . 1963. Coccidia of *Microtus arvalis* Pallas 1778 in Azerbaidzhane (text in Russian). *Izvestiya Akademii Nauk Azerbaidzhanskoi SSR* 4: 61–76.